Observations of Short, Stationary Waves Near a Beach

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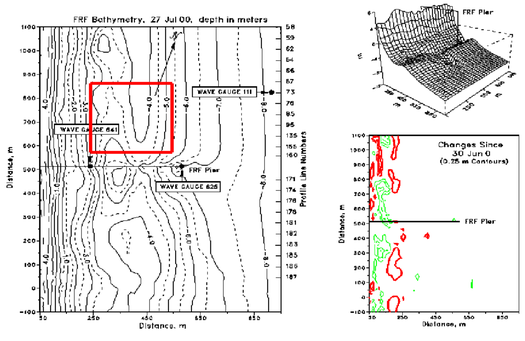
ABSTRACT

During July, 2000 we collected time series' of photographic images over a shoaling wave field near Duck. NC. The image field subtends an area of approximately 1 Km, square. The images are re-mapped onto the Army Field Research Facility coordinate system, a rectilinear system. The mapping results in an RMS registration error of 1-2 meters. Each photo sequence contains 12 images, spaced 2 seconds apart. Each sequence was averaged over the 12 images in order to remove gravity waves. These averages would then yield any time-independent effects such as lens vignetting that might affect the imagery. The averages, in fact, revealed a field of short (about 15m, wavelength) waves that were apparently stationary. The waves appeared shoreward and seaward of the principal sand bar, located in 4 m of water.

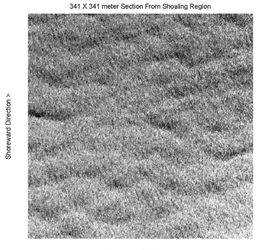
The waves were imaged on 21 July, after the passage of a cold front. Significant wave height was about 90 cm. Averaged images obtained on the afternoon of 22 July, however, showed no stationary waves. The SWH had decreased to 60 cm by this date.



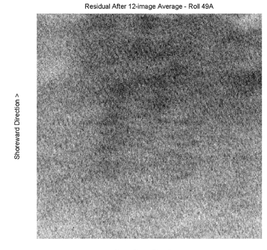
340 X 340 meter square of shoaling wave field was imaged, sequentially, using a computer-controlled camera, hand held, from a single-engine Cessna. Bathymetry was measured on 27 July, 6 days following the airborne photo collect. (Data courtesy of U.S. Army Corps of Engineers Field Research Facility, Duck, NC)

The Raw Data

Photos of shoaling wave field off the beach at the U.S. Army Field Research Laboratory, Duck, NC. Incidence angle approximately 88 degrees under overcast skies.



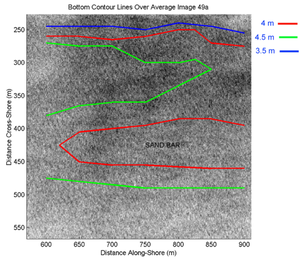
Rectify and geo-locate 12 images in a sequence. Images are separated in time by 2 seconds. Small wave structure can be seen superimposed on swell.



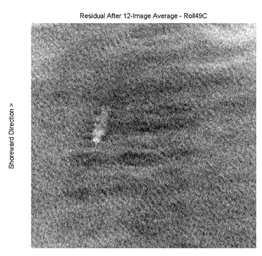
Average 12 such images together, thus eliminating such transient phenomena as freely propagating gravity waves. Short, 15-meter waves remain – apparently stationary over the 22-second time interval.

What Causes These Waves?

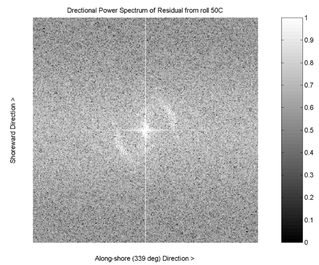
First, are the waves real undulations in the free surface? It was observed that these short waves only begin to appear when the look direction of the camera has a significant component normal to the wave crests. This would be expected if the local surface normal were being modulated by an underlying wave. What candidate sources are there for stationary waves? Background currents such as would result from significant Stokes (wave) transport toward the beach. The Stokes transport increases under the presence of non-linear (steep, short-wavelength) waves. Such a current in combination with bottom relief, can produce stationary undulations in the surface.



Stationary waves from above but with bathymetry superimposed. Definition seems to be best in trough between bar and beach.



Second 22-second average obtained 3 minutes later. Note the effect of the Stokes transport on the bubble cloud resulting from the breaking wave.



2-D power spectrum of 15-meter wave field. Waves are angled at about 30 degrees to the shoreline.

Implications

Bottom bedforms on scales of a few meters (Ex: Gallagher, 1999) have been suspected of playing an important role in the transport of sand and in bar formation in the shoaling region. If these bedforms are appearing in deformations of the free surface, their alignment, formation, and movement could be monitored through accurately registered aerial photographs. Even the bottom stress might be estimated by observing the height of the waves using relevant algorithms.

References

Gallagher, E., 1998, "Mega-Ripple Migration", Nature, Vol 395, Pg 165.